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(54) **METHOD TO MAKE INTERFEROMETRIC TAPER WAVEGUIDE FOR HAMR LIGHT DELIVERY**

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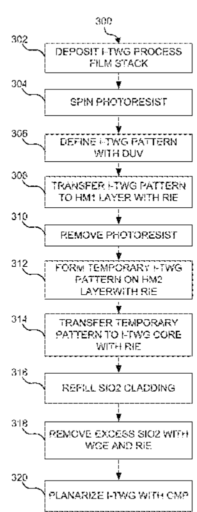
(57) **ABSTRACT**

A method for making an interferometric taper waveguide (I-TWG) with high critical dimension uniformity and small line edge roughness for a heat assisted magnetic recording (HAMR) head, wherein the method includes creating an I-TWG film stack with two hard mask layers on top of an I-TWG core layer sandwiched between two cladding layers, defining a photoresist pattern over the I-TWG film stack using deep ultraviolet lithography, transferring the pattern to the first hard mask layer using reactive ion etching (RIE), forming a temporary I-TWG pattern on the second hard mask layer using RIE, transferring the temporary pattern to the I-TWG core using RIE, refilling the cladding layer, and planarizing using chemical mechanical planarization (CMP).

9 Claims, 4 Drawing Sheets



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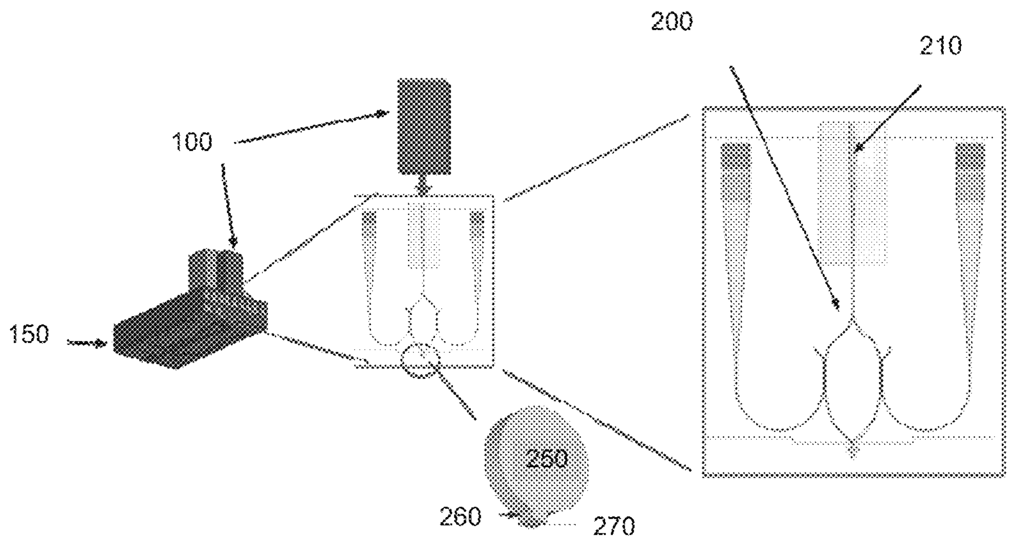


Fig. 1

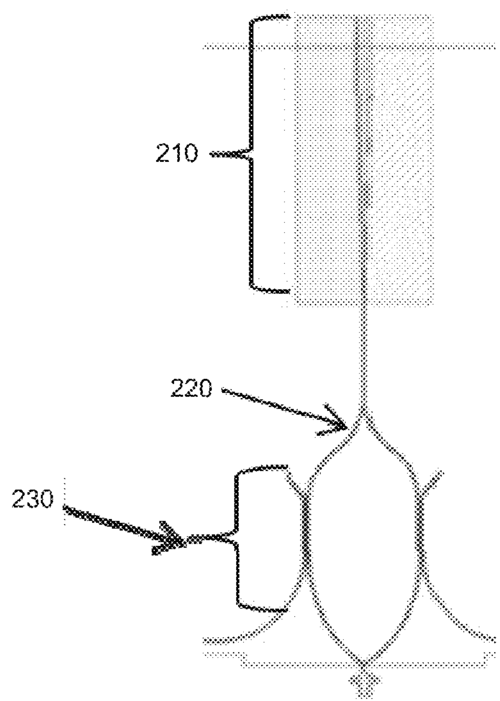


Fig. 2

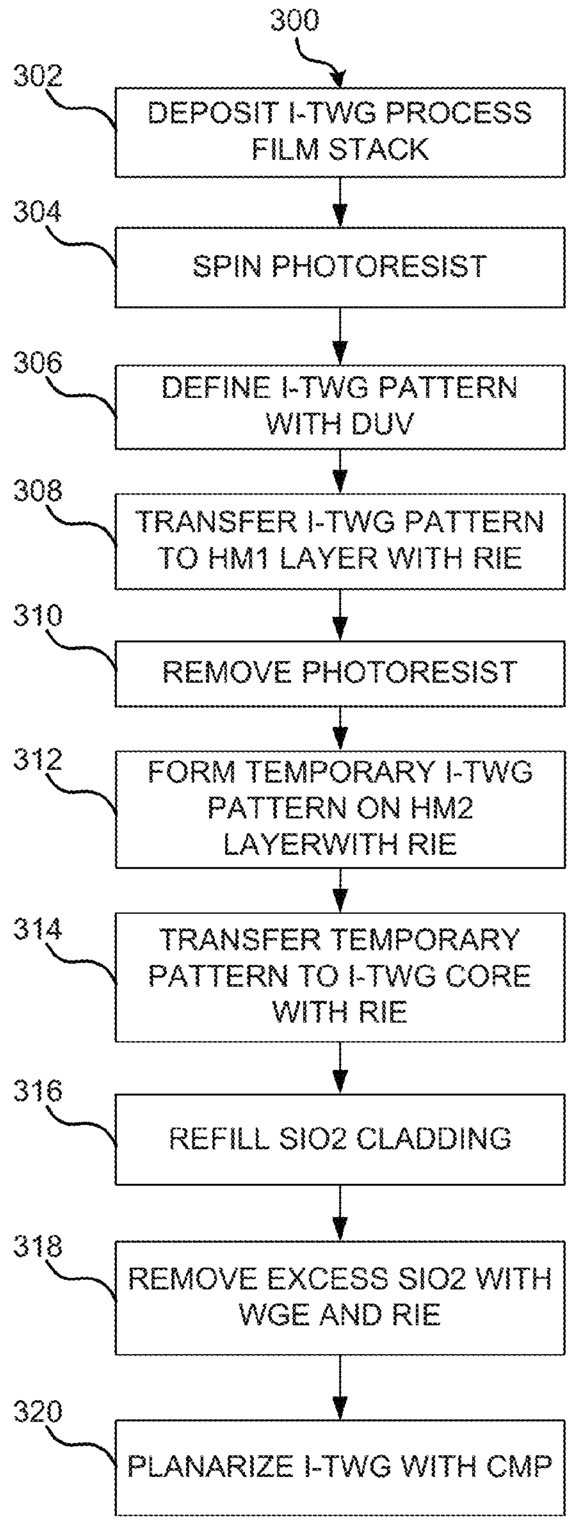

300
302
DEPOSIT I-TWG PROCESS FILM STACK
304
SPIN PHOTORESIST
306
DEFINE I-TWG PATTERN WITH DUV
308
TRANSFER I-TWG PATTERN TO HM1 LAYER WITH RIE
310
REMOVE PHOTORESIST
312
FORM TEMPORARY I-TWG PATTERN ON HM2 LAYERWITH RIE
314
TRANSFER TEMPORARY PATTERN TO I-TWG CORE WITH RIE
316
REFILL SIO2 CLADDING
318
REMOVE EXCESS SIO2 WITH WGE AND RIE
320
PLANARIZE I-TWG WITH CMP

Fig. 3

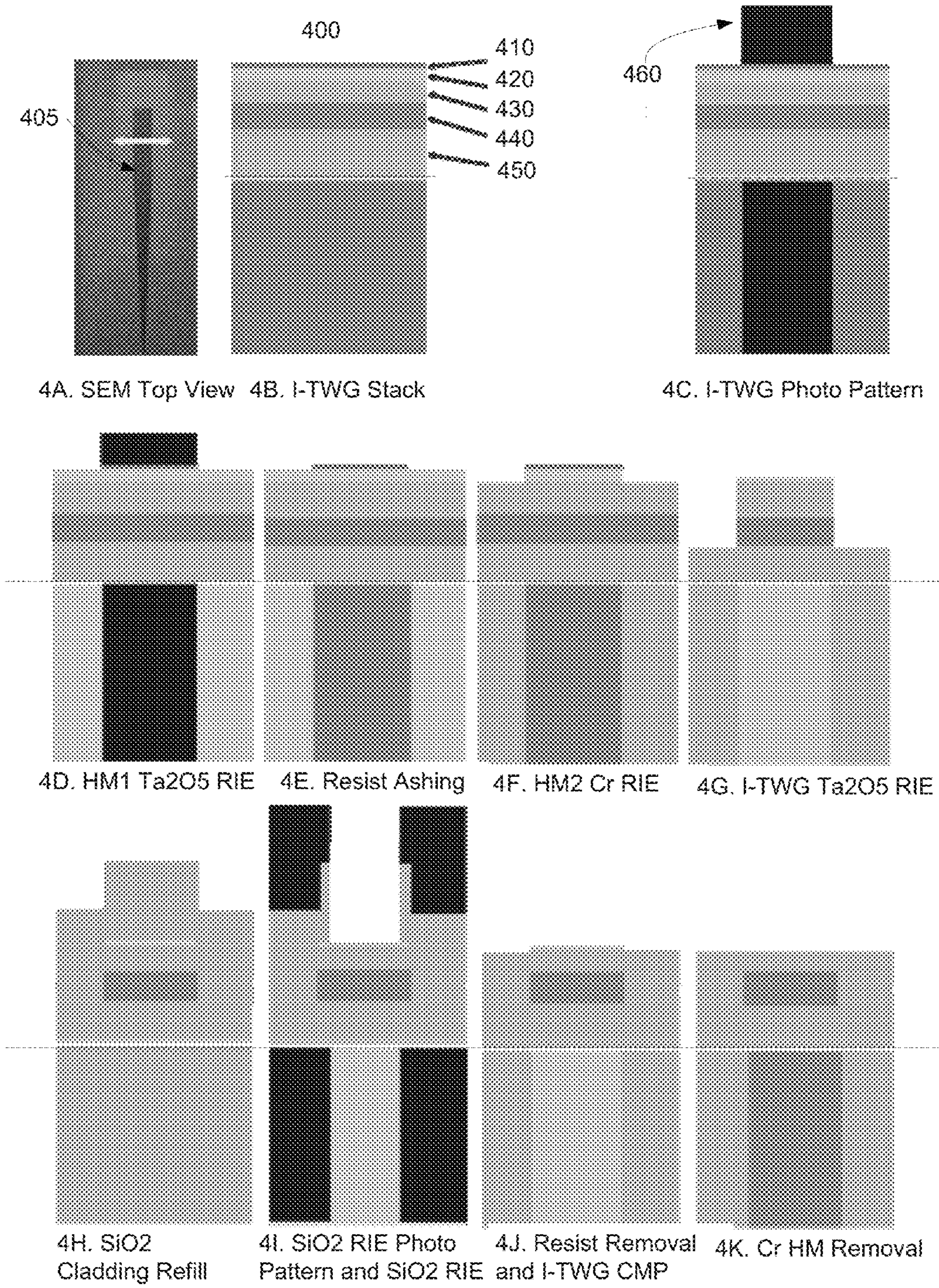
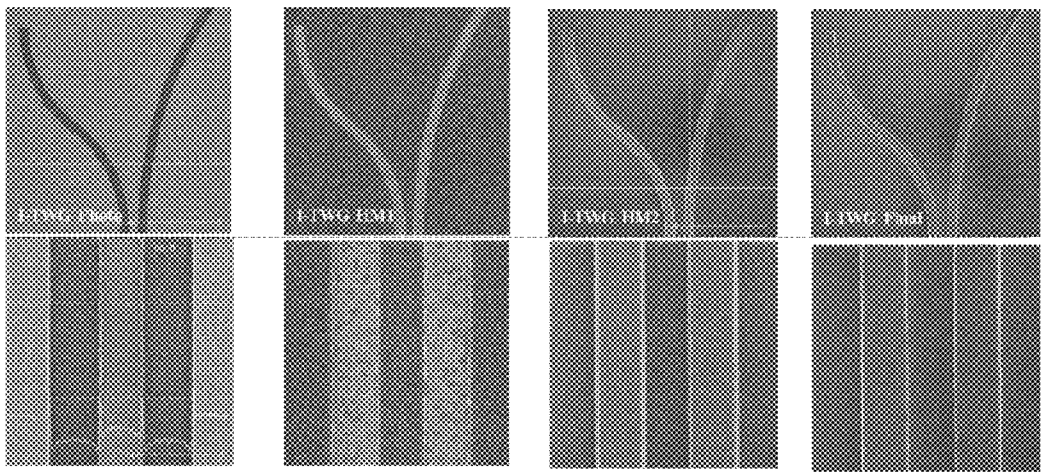

400
405
410
420
430
440
450
460
4A. SEM Top View
4B. I-TWG Stack
4C. I-TWG Photo Pattern
4D. HM1 Ta2O5 RIE
4E. Resist Ashing
4F. HM2 Cr RIE
4G. I-TWG Ta2O5 RIE
4H. SiO2 Cladding Refill
4I. SiO2 RIE Photo Pattern and SiO2 RIE
4J. Resist Removal and I-TWG CMP
4K. Cr HM Removal

Fig. 4



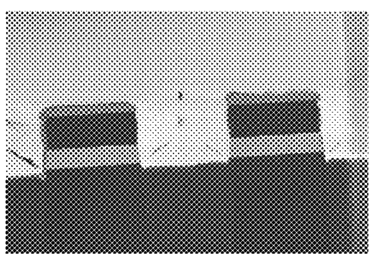
5A
I-TWG photoresist.

5B
I-TWG hardmask 1.

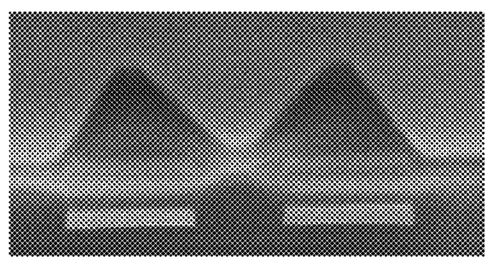
5C
I-TWG hardmask 2.

5D
I-TWG final pattern.

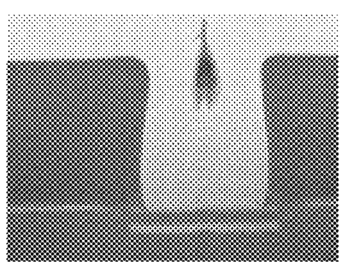
Fig. 5



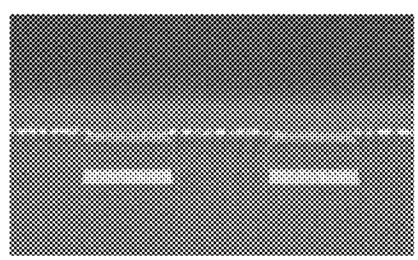
6A. Post I-TWG RIE TEM image at I-TWG directional coupler site.



6B. Post SiO2 refill FEI image at I-TWG directional coupler site.



6C. Post I-TWG WGE FEI image at I-TWG taper site.



6D. Post I-TWG CMP FEI image at I-TWG directional coupler site.

Fig. 6

METHOD TO MAKE INTERFEROMETRIC TAPER WAVEGUIDE FOR HAMR LIGHT DELIVERY

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of and priority to U.S. Provisional Application 61/943,951 filed on Feb. 24, 2014, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to magnetic recording technology, and in particular, to a method for manufacturing a light delivery component for use in heat-assisted magnetic recording media.

BACKGROUND

For all types of substrates, perpendicular magnetic recording (PMR) technology has become more prevalent in magnetic recording media with the goal of increasing areal density. Areal density is generally limited by the media's ability to, at a sufficiently small bit size, write a data bit, read back the same data bit, and maintain the magnetic characteristics of the data bit over time. For magnetic media, these parameters are controlled by the materials coercivity. However, there exists a threshold wherein the coercivity is so high, and the bit size so small, that the writing element must use an impractically high magnetic field to affect change to a data bit. The advent of heat-assisted magnetic recording (HAMR) media addresses this problem by applying heat to a data bit during a write operation to lower the coercivity to a writable level, and then removing the heat to allow the coercivity to return to a high level to keep the data bit stable.

By using HAMR technology, areal density in hard disk drives can be extended beyond 1 Tb/in^2. FIG. **1** illustrates a HAMR head light delivery system design. Laser light from an external laser diode (LD) **100** is coupled into interferometric taper waveguide (I-TWG) **200** by mode converter (MC) **210**, and then delivered through I-TWG **200** to near field transducer (NFT) **250** at air bearing surface (ABS) **270**, which focuses the laser generated light energy into a less than 50 nm spot on the PMR media surface.

The structure of an I-TWG **200**, as shown in FIG. **2**, includes several critical components including mode converter taper **210**, splitter **220**, and directional coupler **230**. Constructing these components into a unified structure on a single wafer with homogenous deposition and etching technologies is challenging because the components have very different dimensional scale, but dimensional accuracy is extremely important to operational performance of the HAMR. For example, the I-TWG taper angle and length, waveguide critical dimension uniformity (CDU), line edge roughness (LER), splitter asymmetry, and MC-to-taper overlay are critical to the HAMR's signal-to-noise ratio (SNR), head longevity, and power consumption. Directional coupler **230** is used to return some of the laser light to the backside of slider **150** (as shown in FIG. **1**) for laser alignment adjusting. However, dimensional accuracy necessary to control the taper angle and length, CDU, LER, splitter asymmetry, and MC-to-taper overlay is difficult to control, particularly when building the I-TWG on a single substrate. Accordingly, currently available I-TWG methods tend to use more expensive, multi-substrate construction and tend to result in structures with variances in these critical parameters. The resulting I-TWG's are not ideal in their efficiency, power consumption, and head life.

BRIEF SUMMARY OF THE DISCLOSURE

The present disclosure is directed towards magnetic recording media, and in particular, a method for making an I-TWG for a HAMR head on a single substrate with increased dimensional accuracy. Embodiments of this disclosure describe a method for making an I-TWG for a HAMR head that efficiently delivers laser light from the backside of a slider to an ABS region, resulting in an HAMR with extended head life and reduced power consumption.

In one example, a method for manufacturing a waveguide includes depositing a film stack with two different hard mask layers on a cladding-core-cladding sandwich and defining a first pattern in a photoresist layer on the film stack. A method for making a waveguide may also include transferring the pattern to a first hard mask layer, removing the photoresist layer, and forming a second pattern in a second hard mask layer patterned from the first pattern in the first hard mask layer. A method for making a waveguide may also include transferring the second pattern to the core layer and planarizing a top surface of the waveguide.

In some examples, a first hard mask layer is Ta_2O_5, a second hard mask layer is Cr, and the cladding layers are SiO_2. Various material compositions of the hard mask and cladding layers are possible as would be known to one of ordinary skill in the art.

In some examples, the defining of the I-TWG pattern in photoresist is accomplished with deep ultraviolet lithography, the transferring the pattern to the hard mask layers and the core layer is accomplished with reactive ion etching processes. In further examples, the planarizing is chemical mechanical planarizing.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments are illustrated by way of example, and not limitation, in the figures of the accompanying drawings in which:

FIG. **1** illustrates an example interferometric taper waveguide (I-TWG) as used in heat-assisted magnetic recording media (HAMR);

FIG. **2** is a schematic diagram of an I-TWG;

FIG. **3** is a diagram illustrating a process for making an I-TWG.

FIG. **4**A is a scanning electron microscope (SEM) top view of an I-TWG formed on a substrate;

FIG. **4**B illustrates a cross-section view and a top view of an I-TWG film stack;

FIG. **4**C illustrates a cross-section view and a top view of an I-TWG film stack with photoresist pattern deposited thereon;

FIG. **4**D illustrates a cross-section view and a top view of an I-TWG film stack following a photolithography pattern forming process and a reactive ion etch (RIE) pattern forming process;

FIG. **4**E illustrates a cross-section view and a top view of an I-TWG film stack following a photoresist removal process;

FIG. **4**F illustrates a cross-section view of an I-TWG film stack following a second RIE pattern forming process;

FIG. **4**G illustrates a cross-section view and a top view of an I-TWG film stack following a third RIE pattern forming process;

FIG. 4H illustrates a cross-section view and a top view of an I-TWG film stack following a cladding refill process;

FIG. 4I illustrates a cross-section view and a top view of an I-TWG film stack following a photolithography pattern forming process step and a fourth RIE pattern forming process;

FIG. 4J illustrates a cross-section view and a top view of an I-TWG film stack following a planarization process;

FIG. 4K illustrates a cross-section view and a top view of an I-TWG film stack following a hard mask removal process;

FIG. 5A is a SEM top view image of an I-TWG photoresist pattern as part of a process to make an I-TWG;

FIG. 5B is a SEM top view image of an I-TWG hardmask 1 (HM1) layer pattern as part of a process to make an I-TWG;

FIG. 5C is a SEM top view image of an I-TWG hardmask 1 (HM2) layer pattern as part of a process to make an I-TWG;

FIG. 5D is a SEM top view image of an I-TWG final pattern;

FIG. 6A is a transmission electron microscope (TEM) image of an I-TWG directional coupler site following a reactive ion etch (RIE) process;

FIG. 6B is a SEM image of an I-TWG directional coupler site following an SiO2 refill process;

FIG. 6C is a SEM image of an I-TWG taper site following a waveguide etch (WGE) process;

FIG. 6D is a SEM image of an I-TWG directional coupler site following a chemical mechanical planarization (CMP) process.

DETAILED DESCRIPTION

In the following description, numerous specific details are set forth to provide a thorough understanding of various embodiment of the present disclosure. It will be apparent to one skilled in the art, however, that these specific details need not be employed to practice various embodiments of the present disclosure. In other instances, well known components or methods have not been described in detail to avoid unnecessarily obscuring various embodiments of the present disclosure.

As disclosed herein, a process for manufacturing a waveguide includes depositing a film stack wherein the film stack includes a first hard mask layer, a second hard mask layer, a first cladding layer, a core layer, and a second cladding layer. Some embodiments include defining a first pattern in a photoresist layer, transferring the first pattern to the first hard mask layer, and removing the photoresist layer. Several embodiments may also include forming a second pattern in the second hard mask layer patterned from the first pattern in the first hard mask layer, and transferring the second pattern to the core layer. Some embodiments my also include planarizing a top surface of the waveguide. In some examples, the core layer is deposited on the second cladding layer, the first cladding layer is deposited on the core layer, the second hard mask layer is deposited on the first cladding layer, and the first hard mask layer is deposited on the second hard mask layer. Further, in some examples of the disclosure, the first hard mask layer comprises Ta_2O_5, the second hard mask layer comprises Cr, the first cladding layer comprises SiO_2, the core layer comprises Ta_2O_5, and the second cladding layer comprises SiO_2. The deposit and removing processes disclosed may include reactive ion etching, deep ultraviolet lithography, chemical mechanical planarization, and other lithography and manufacturing processes as are known in the art.

FIG. 1 illustrates an example interferometric taper waveguide (I-TWG) as used in heat-assisted magnetic recording media (HAMR). A HAMR device includes a laser 100 mechanically coupled to a slider 150 and an I-TWG. FIG. 1 illustrates a blown up view of the I-TWG 200 coupled to a mode converter 210. The I-TWG and mode converter structures may be constructed on a single substrate, or may be an assembly of components constructed on different substrates. The waveguide structures of the I-TWG may be less than a few microns wide, but may also scale up to larger sizes depending on the wavelength of the laser. Laser wavelength may be selected for efficient delivery of heat through the I-TWG to the media surface, as would be known in the art. For example, laser diodes that emit wavelengths in the range of 375 nm to 830 nm may be used. The type of laser diode selected only affects the design of the I-TWG to the extent that the critical dimensions of the waveguide may be optimally selected depending on the type of laser diode used. Near field transducer 250 couples to the opposite end of I-TWG 200 from mode converter 210. Near field transducer 250 includes an air bearing surface 270.

FIG. 2 is a schematic diagram of an I-TWG. Mode converter 210 is optically couples to splitter 220. Splitter 220 optically couples to directional coupler 230. Referring to FIGS. 1 and 2, optimally, the critical dimensions uniformity of the I-TWG will vary by less than 5 nm.

FIG. 3 is a diagram illustrating a process for making an I-TWG. Referring now to FIG. 3, one embodiment of a method for making an I-TWG 300 includes the steps of depositing an I-TWG film stack at step 302, spinning a photoresist pattern at step 304, and defining an I-TWG pattern with deep ultraviolet (DUV) lithography at step 306. The method may also include transferring the I-TWG pattern to a first hardmask layer (HM1) using a reactive ion etch (RIE) process at step 308, and removing the photoresist at step 310. The method may also include forming a temporary I-TWG pattern on a second hardmask layer (HM2) using a RIE process at step 312, and transferring the temporary pattern to an I-TWG core layer with a RIE process at step 314. In some embodiments, a process for making an I-TWG also includes refilling a SiO2 cladding layer around the I-TWG structure at step 316, removing excess SiO2 with a waveguide etch (WGE) process and/or RIE process at step 318, and planarizing the I-TWG structure with chemical mechanical planarization (CMP) at step 320.

FIG. 4A is a scanning electron microscope (SEM) top view of an I-TWG formed on a substrate. Referring now to FIG. 4A, the I-TWG structure may be formed on a SiO2 substrate, such as a wafer, using lithographic processes. FIG. 4A further demonstrates the taper shaped I-TWG pattern 405 from a top down view. FIGS. 4B through 4K illustrate cross section top views of the I-TWG structure as it is formed, as described in several embodiments of this disclosure, using processes including photolithography, reactive ion etching (RIE), and chemical mechanical planarization (CMP) steps.

FIG. 4B illustrates a cross-section view and a top view of an I-TWG film stack. Referring now to FIG. 4B, and also to FIG. 3, an I-TWG film stack as used in some embodiments of the disclosure may be formed using material deposition techniques as would be known to one of ordinary skill in the art. In some embodiments, the I-TWG film stack includes a first hard mask layer (HM1) 410, a second hard mask layer (HM2) 420, a top cladding layer 430, an I-TWG core layer 440, and a bottom cladding layer 450. In some embodiments, the HM1 layer 410 comprises Ta_2O_5 or Ta, the HM2 layer 420 comprises Cr or Ru, the top cladding layer 430 comprises SiO2, the I-TWG core layer 440 comprises Ta_2O_5, and the bottom cladding layer 450 comprises SiO_2. Other material stacks may be used as would be known to one of ordinary skill in the art wherein the general structure includes two hard mask layers **410** and **420** and an I-TWG core **440** sandwiched by two cladding layers **430** and **450**. As shown in FIG. **4**A, a bi-layer hard mask deposition of Cr and Ta_2O_5 may be used to provide sufficient protection for the I-TWG structure during the RIE processes. The HM**1** layer **410** may also be used as a CMP stop layer during I-TWG final planarization in step **320**.

FIG. **4**C illustrates a cross-section view and a top view of an I-TWG film stack with photoresist pattern deposited thereon. Referring now to FIG. **4**C, and still referring to FIG. **3**, a photoresist layer **460** may be spun on the film stack in step **304**. A deep ultraviolet (DUV) photolithography process may then be used to define the I-TWG pattern in the photoresist layer **460** at step **306**. The I-TWG pattern may then be transferred to the HM**1** layer **410** through an RIE process in step **308**.

FIG. **4**D illustrates a cross-section view and a top view of an I-TWG film stack following both a photolithography pattern definition process and a reactive ion etch (RIE) pattern transferring process. Referring now to FIG. **4**D, and still referring to FIG. **3**, the relative position of the taper and mode converter structures of the I-TWG may be precisely controlled using DUV scanner photolithography process at step **308**. Alternatively, in some embodiments of the disclosure, other photolithography and/or ion etching or milling processes, or combinations thereof, may be used to form the I-TWG structure as would be known to one skilled in the art. Referring again to FIGS. **3** and **4**C, the photolithography layer **460** may be removed using a dry etching process, for example, using a resist ashing process at step **310**. In other embodiments of the disclosure, photoresist removal techniques specific to the type of resist use, but non-corrosive to the remaining HM**1** and HM**2** layers, such as chemical stripping, may be used.

FIG. **4**E illustrates a cross-section view and a top view of an I-TWG film stack following a photoresist removal process. Referring now to FIG. **4**E, the resulting I-TWG structure has a clean, resist-free surface with an I-TWG pattern etched on the HM**1** layer **410**. Referring again to FIG. **3**, a second RIE process **312**, using the already formed I-TWG pattern in HM**1** layer **410**, may be used to form a temporary I-TWG pattern in HM**2** layer **420**.

FIG. **4**F illustrates a cross-section view and a top view of an I-TWG film stack following the second RIE pattern forming process **312**. Referring now to FIG. **4**F, a temporary I-TWG pattern is formed in HM**2** layer **420**. Referring again to FIGS. **3** and **4**B, the temporary I-TWG pattern formed in step **312** may be transferred through cladding layer **430** to I-TWG core layer **440** using a third RIE process **314**.

FIG. **4**G illustrates a cross-section view and a top view of an I-TWG film stack following the third RIE pattern forming process **314**. Referring now to FIG. **4**G, the I-TWG pattern is successfully transferred to I-TWG core layer **440** to form a final I-TWG structure. Further, the HM**1** layer **410** may also be removed by RIE process **314**. However, RIE process **314** also may remove substantial portions of cladding layer **450**. Referring again to FIG. **3**, SiO2 cladding may be re-deposited around the I-TWG structure in step **316**. In some embodiments of the disclosure, the cladding material may be other selected from other cladding materials known to one of skill in the art.

FIG. **4**H illustrates a cross-section view and a top view of an I-TWG film stack following the cladding refill process **316**. Referring now to FIG. **4**H, the final I-TWG structure formed in I-TWG core layer **440** is embraced by cladding material that was refilled in step **316**. Referring again to FIG. **3**, excess cladding material may be removed using a waveguide etch (WGE) process and/or a fourth RIE process at step **318**.

FIG. **4**I illustrates a cross-section view and a top view of an I-TWG film stack during the WGE photolithography process from step **318**. Referring now to FIG. **4**I, a second photoresist WGE pattern may be defined on the I-TWG structure and excess cladding material deposited in step **316** may be removed by a fourth RIE process. In other embodiments of the disclosure, excess cladding material may be removed using other removal processes as would be known to one of skill in the art. Referring again to FIG. **3**, the resulting I-TWG structure shown in FIG. **4**I may be planarized using a chemical mechanical planarization (CMP) process at step **320**.

FIG. **4**J illustrates a cross-section view and a top view of an I-TWG film stack following CMP process **320**. The resulting structure includes an I-TWG structure surround by cladding, and planarized, but with HM**2** layer **420** still capping the top of the structure. HM**2** layer **420** may be subsequently removed using a wet etch process, or other mask removal processes as would be known to one of skill in the art.

FIG. **4**K illustrates a cross-section view and a top view of an I-TWG film stack following the HM**2** removal process. Referring now to FIG. **4**K, a resulting I-TWG structure with cladding is completely flat, allowing for easy integration with other HAMR components while the I-TWG structure is still attached to its substrate wafer.

FIG. **5**A is a SEM top view image of an I-TWG with photoresist I-TWG pattern. Now referring to FIG. **5**A, and again referring to FIG. **3**, a photoresist I-TWG pattern may be defined over the I-TWG film stack at step **304**. The photoresist pattern forms the shape of the taper waveguide components (e.g. splitter **220** and directional coupler **230** as shown in FIG. **2**).

FIG. **5**B is a SEM top view images of an I-TWG hard mask layer HM**1** **410** following transfer of the I-TWG pattern at step **308** and removal of the photoresist at step **310**. Referring to FIG. **5**B, the I-TWG structure is clearly defined in HM**1**.

FIG. **5**C is a SEM top view images of an I-TWG hard mask layer HM**2** **420** following formation of the temporary I-TWG pattern at step **312**. Referring to FIG. **5**C, the I-TWG structure is clearly defined in HM**2**.

FIG. **5**D is a SEM top view image of an I-TWG final pattern in I-TWG core layer **440**.

FIG. **6**A is a transmission electron microscope (TEM) cross-section image of an I-TWG directional coupler site following a reactive ion etch (RIE) process at step **314**. Referring to FIG. **6**A, the cross-section of the directional coupler section of the I-TWG structure can be seen with HM**2** layer **420** remaining on cladding layer **430**, which in turn is layered on I-TWG core layer **440**.

FIG. **6**B is a SEM image of the same I-TWG directional coupler site shown in FIG. **6**A following SiO2 refill process **316**. Referring to FIG. **6**B, the dark SiO2 cladding material can be seen filling in the gaps left from RIE process **314**.

FIG. **6**C is a SEM image of an I-TWG taper site following WGE process **318**.

FIG. **6**D is a SEM image of the same I-TWG directional coupler site shown in FIGS. **6**A and **6**B following CMP process **320**. Referring to FIG. **6**D, the resulting I-TWG directional coupler structure is fully clad in SiO2, and completely flat, enabling easy integration with other HAMR components while still on the wafer substrate (i.e. integration with a writer).

The process embodied by the disclosure illustrated by FIGS. **3** and **4**, along with process variations as would be known to one of ordinary skill in the art, can result in an

I-TWG structure with superior critical dimension uniformity (CDU) and small line edge roughness, and that is capable of delivering laser light from the backside of the slide **150** to NFT **250**, and coupling ABS region **270** to form a less than 50 nm hot spot on the surface of the recording media with minimal power usage.

In one embodiment, a process for manufacturing an interferometric taper waveguide (I-TWG) for heat assisted magnetic recording (HAMR) laser light delivery comprises depositing an I-TWG film stack, spinning a photoresist pattern, defining an I-TWG pattern using deep ultraviolet lithography (DUV), transferring the I-TWG pattern to a first hard mask layer using reactive ion etching (RIE), removing the photoresist layer, forming a temporary I-TWG pattern on a second hard mask layer using RIE, creating a final I-TWG pattern by transferring the temporary I-TWG pattern to an I-TWG core layer using RIE, refilling cladding around the final I-TWG pattern, removing excess cladding using waveguide etching lithography (WGE) and RIE, planarizing using chemical mechanical planarization (CMP), and removing the second hard mask layer using wet etching. In some embodiments, the I-TWG film stack comprises a first hard mask layer of Ta_2O_5 or Ta, a second hard mask layer of Cr or Ru, a top cladding layer of SiO_2, an I-TWG core layer of Ta_2O_5, and a bottom cladding layer of SiO_2.

Although described above in terms of various exemplary embodiments and implementations, it should be understood that the various features, aspects and functionality described in one or more of the individual embodiments are not limited in their applicability to the particular embodiment with which they are described, but instead can be applied, alone or in various combinations, to one or more of the other embodiments of the application, whether or not such embodiments are described and whether or not such features are presented as being a part of a described embodiment. Thus, the breadth and scope of the present application should not be limited by any of the above-described exemplary embodiments.

The terms "over," "under," "between," and "on" as used herein refer to a relative position of one media layer with respect to other layers. As such, for example, one layer disposed over or under another layer may be directly in contact with the other layer or may have one or more intervening layers. Moreover, one layer disposed between two layers may be directly in contact with the two layers or may have one or more intervening layers. In contrast, a first layer "on" a second layer is in contact with that second layer. Additionally, the relative position of one layer with respect to other layers is provided assuming operations are performed relative to a substrate without consideration of the absolute orientation of the substrate.

Terms and phrases used in this document, and variations thereof, unless otherwise expressly stated, should be construed as open ended as opposed to limiting. As examples of the foregoing: the term "including" should be read as meaning "including, without limitation" or the like; the term "example" is used to provide exemplary instances of the item in discussion, not an exhaustive or limiting list thereof; the terms "a" or "an" should be read as meaning "at least one," "one or more" or the like; and adjectives such as "conventional," "traditional," "normal," "standard," "known" and terms of similar meaning should not be construed as limiting the item described to a given time period or to an item available as of a given time, but instead should be read to encompass conventional, traditional, normal, or standard technologies that may be available or known now or at any time in the future. Likewise, where this document refers to technologies that would be apparent or known to one of ordinary skill in the art, such technologies encompass those apparent or known to the skilled artisan now or at any time in the future.

The presence of broadening words and phrases such as "one or more," "at least," "but not limited to" or other like phrases in some instances shall not be read to mean that the narrower case is intended or required in instances where such broadening phrases may be absent. The use of the term "module" does not imply that the components or functionality described or claimed as part of the module are all configured in a common package. Indeed, any or all of the various components of a module, whether control logic or other components, can be combined in a single package or separately maintained and can further be distributed in multiple groupings or packages or across multiple locations.

Additionally, the various embodiments set forth herein are described in terms of exemplary block diagrams, flow charts and other illustrations. As will become apparent to one of ordinary skill in the art after reading this document, the illustrated embodiments and their various alternatives can be implemented without confinement to the illustrated examples. For example, block diagrams and their accompanying description should not be construed as mandating a particular architecture or configuration.

What is claimed is:

1. A method for manufacturing an interferometric taper waveguide (I-TWG), the method comprising:

depositing a film stack, the film stack comprising a plurality of hard mask layers and a cladding-core sandwich layer, wherein the plurality of hard mask layers is located above the cladding-core sandwich layer, and the cladding-core sandwich layer comprises a top cladding layer, a bottom cladding layer, and a core layer located between the top cladding layer and the bottom cladding layer;

spinning a photoresist layer on a top hard mask layer;

defining with a first microfabrication process an I-TWG pattern in the photoresist layer;

transferring with a second microfabrication process the I-TWG pattern to the top hard mask layer;

removing the photoresist;

forming with a third microfabrication process the I-TWG pattern in a bottom hard mask layer;

transferring with a fourth microfabrication process the I-TWG pattern to the core layer;

refilling cladding material;

removing with a fifth microfabrication process excess cladding material;

planarizing with a sixth microfabrication process a top surface of the I-TWG; and

removing with a seventh microfabrication process the bottom hard mask layer.

2. The method of claim **1** wherein each of the plurality of hard mask layers comprises Ta_2O_5, Ta, Cr, or Ru.

3. The method of claim **1** wherein the cladding layers comprise SiO_2 and the core layer comprises Ta_2O_5.

4. The method of claim **1** wherein the first microfabrication process comprises using deep ultraviolet lithography.

5. The method of claim **1** wherein the second microfabrication process, the third microfabrication process, and the fourth microfabrication process each comprise using reactive ion etching.

6. The method of claim **1** wherein the fifth microfabrication process comprises using waveguide etching and reactive ion etching.

7. The method of claim **1** wherein the sixth microfabrication process comprises using chemical mechanical planarization.

8. The method of claim **1** wherein the seventh microfabrication process comprises using wet etching.

9. The method of claim **1** wherein the I-TWG pattern comprises a taper waveguide pattern, a directional coupler pattern, and a splitter pattern.

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